



Panel to Review  
the V-22 Program

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# **V-22 PROGRAM REVIEW**

## **Final Deliberations Panel to Review the V-22 Program**

**April 18, 2001**



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## Purpose

- **To present the findings of the sub-panels to the full Panel for deliberation and approval**
- **To decide on final conclusions and recommendations for the report to the Secretary of Defense**



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## The Panel

- **Secretary's response to accident history and testing deficiencies**
- **Established December 15, 2000**
- **Federal Advisory Committee Act**
- **Members**
  - **General John R. Dailey, USMC (Ret.) (Chairman)**
  - **Mr. Norman R. Augustine**
  - **General James B. Davis, USAF (Ret.)**
  - **Dr. Eugene E. Covert**
- **Charter**
  - **Assess effects on safety and combat effectiveness of**
    - **Training**
    - **Engineering and design**
    - **Production and quality control**
    - **Suitability to satisfy operational requirements**
    - **Performance and flight safety**
- **Report to Secretary by April 24, 2001**



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## Panel Activities

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- Jan 11, 12 Fact finding, program overview
  - Feb 26 Fact finding, mishap briefings, data gathering
  - Mar 5-8 Fact finding trips
    - » V-22 Training Squadron, Marine Corps Air Station, New River, NC
    - » Special Operations Command, Tampa, FL
    - » Bell Helicopter, Fort Worth and Amarillo, TX
    - » Boeing Helicopter, Philadelphia, PA
  - Mar 9 Open meeting: public comments
  - Apr 12, 13 Fact finding, final information requests
  - Apr 16, 17 Subpanel meetings: analysis and preliminary findings
  - **Apr 18 Open meeting: Panel deliberations**
  - Apr 24 Secretary of Defense briefing
  - Apr 30 Final report published on World-Wide-Web
  - May 1 Senate Armed Services Committee Hearing
  - May 1 House Armed Services Committees (Procurement Sub)



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## **Panel to Review the V-22 Program Agenda**

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- **Specific Findings**
  - **Safety**
    - **Crashworthy Fuel Tanks**
    - **Flight Control System Reliability**
    - **Vortex Ring State**
    - **Crew Qualifications for OPEVAL**
    - **Pilot training**
    - **Downwash**
    - **Autorotation**
    - **Tiltrotor Safety**
    - **System Safety Program**
    - **Production Quality**



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## **Panel to Review the V-22 Program Agenda (cont)**

- **Specific Findings Continued**
  - **Combat Effectiveness**
    - **Reliability and Availability**
    - **Maintainability**
    - **Interactive Electronic Technical Manual**
    - **Maintenance and Availability Reporting: NALCOMIS (Optimized)**
    - **Maintenance training**
    - **Diagnostic Capability**
  - **Programmatics**
    - **Program Communications**
    - **Systems Engineering\Risk Management**
    - **Program Affordability**
    - **Program Reserves**
    - **CV-22 Block 0 development**
    - **Spares Planning and Provisioning**
    - **Engineering Changes**
- **Analysis of Alternatives**
- **The Way Forward (Summary Recommendations)**



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## **V-22 Program Issues**

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## **Safety**



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## Crashworthy Fuel Cells Discussion

- **Requirement states need for crashworthy fuel cells**
- **First two Low Rate Initial Production (LRIP) lots, aircraft 1 through 11, were configured with extensible fuel cells which passed drop test (but not in sponsons)**
- **All aircraft are equipped with extensible fuel tanks in the wings which will be drop tested in a wing**
- **Lots 3 and 4 (through A/C 29) were outfitted with new non-extensible design which failed drop test (test tank leaked after 65 ft. drop)**
- **V-22 Program directed redesign of sponson fuel cells effective aircraft 30 and subsequent**
- **There is no retrofit money in the program**
- **Program did a risk assessment to justify keeping the non-compliant fuel cells in earlier aircraft (RAC 1D)**
- **Training Squadron aircrew expressed concern that their aircraft will not be retrofitted with compliant tanks**



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## **Crashworthy Fuel Cells Potential Conclusion**

- a. The sponson fuel cell upgrade planned for aircraft 30 and subsequent will meet the requirement for crashworthy fuel cells**
- b. Although the program risk assessment satisfied the Program Manager that the non-compliant fuel cells are safe for flight, the concerns expressed by the training squadron should be addressed**



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## **Crashworthy Fuel Cells Potential Recommendations**

- a. The Program should plan to retrofit all operational aircraft with crashworthy fuel cells at the first opportunity.**
  - **LRIP 1 and 2 aircraft extensible fuel cell should be tested in a sponson against crashworthiness specification or replaced by compliant fuel cells**
  - **LRIP 3 and 4 aircraft should be retrofitted with compliant fuel cells**

*And, in the meantime,*
- b. Communicate the rationale for interim risk acceptance to the operators**



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## **Flight Control System Reliability Discussion**

- **Flight Control System Hardware**
  - **Designed to high overall reliability goal of  $1 \times 10^{-7}$**
  - **Requirement calls for Fail-Operational / Fail-Safe (FO/FS) architecture (with “exceptions”)**
  - **Single point failure exceptions treated with special care (Critical Parts List)**
    - **Material selection**
    - **Special inspections**
    - **Life tracking**
    - **Special treatment in maintenance plans (inspections, etc.)**
  - **Other “exceptions” to FO/FS requirement mandate no special handling by NAVAIR, Defense Contract Management Agency, company reliability/quality programs, or operational maintenance plans (North Carolina mishap Hyd 1/3 line is an example)**
    - **No special inspections (production or operational) required for this Fail Safe line compared to other Fail Operational lines**
    - **Feb 00 flight failure of Hyd 2/3 line in right nacelle reported as maintenance, not safety issue**
  - **Operational environment effects are worse than predicted...result: higher than expected failure rate of hydraulic components**
  - **Tiger Team looking at all aspects of hydraulic design and support**



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## Flight Control System Reliability Discussion

- **Flight Control System Software**
  - **Prior to North Carolina mishap, integrated hardware/software testing was judged to be adequate**
  - **Integrated software/flight control system anomaly that was a factor in the mishap was not foreseen**
  - **Findings of the mishap investigation resulted in upgrades to Boeing integrated flight control test facility**
    - **man-in-the-loop,**
    - **flight software and computers,**
    - **loaded flight control hydraulics**
  - **More integrated testing planned**
    - **Emergency procedures**
    - **Failure cases**
  - **t verification**
  - **and validation processes**



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## **Flight Control System Reliability Potential Conclusions**

### **Hardware**

- a. V-22 flight control hydraulic components are experiencing failures at higher rates than predicted. Flight safety is therefore highly dependent upon the redundancy features in the system.**
- b. Inaccurate predictions of component reliability affect spares planning, operational suitability, squadron staffing, and flight safety.**
- c. NAVAIR policy currently requires that special attention (materials, tolerances, quality inspections, tracking, etc) be applied to all single point failure modes in the flight control system, but does not require any special attention be given to other exceptions to the flight control redundancy design criterion (i.e. the mishap hydraulic line).**

### **Software**

- The North Carolina mishap identified limitations in the V-22 Program's flight control software development and testing**
- The complexity of the V-22 flight control system demands a thorough software risk analysis capability during development**
- The complexity of the V-22 flight control system demands a highly integrated software/hardware/man-in-the-loop test capability**



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## **Flight Control System Reliability Potential Recommendations**

### **Hardware**

- a. Continue to improve hydraulic system component reliability**
- b. Instrument the test nacelle for acoustics as well as the other current vibration and temperature measurements**
- c. Take appropriate steps to mitigate the risk of loss of hydraulic system integrity (eg. chafing, fittings, leaks, vibration).**
- d. Develop techniques tools and methods for timely identification of hydraulic line chafing**
- e. Assess the process used by V-22 contractors to predict component reliability numbers, and take steps to improve**
- f. Develop appropriate controls (design and life cycle support) for all exceptions to flight control system redundancy requirements (not just single point failures)**

### **Software**

- The V-22 Program should conduct a comprehensive flight control software risk assessment prior to return to flight**
- Conduct an independent flight control software development process review of the V-22 Program with an emphasis on integrated system safety.**
- The Program should not return to flight until the flight procedure and flight control software test cases have been reviewed for adequacy, and evaluated in the integrated test facilities.**



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## **The Mirana Mishap and Vortex Ring State Discussion**

- **From the JAG Investigation**
  - **Primary Cause: Vortex Ring State (Power Settling)**
  - **Contributing Cause: Poor formation flight coordination**
- **Key factors from investigation and top level analysis**
  - **Lead aircraft continued steep tailwind descent despite the 800 fpm/40KCAS warning in NATOPS**
  - **Night formation flight coordination was poor (conversion timing and deceleration was unsynchronized, adding to sink rate problem for wingman)**
  - **NAVAIR development testing was limited to that required to clear 800 fpm and 40 KCAS. Further testing was deferred to later**
  - **V-22 is vulnerable to VRS (this was forecast by engineering community)**
  - **V-22 asymmetric VRS is characterized by rapid roll excursion (unforecast by engineering community)**
  - **NATOPS coverage of VRS was limited and misleading (new NATOPS coverage of the subject more appropriate to the risk involved)**
  - **NATOPS discussion of formation approaches lacks inter-aircraft coordination (i.e. communicate to coordinate nacelle conversion)**



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## **The Mirana Mishap and Vortex Ring State Potential Conclusions**

- a. Performance of the mishap flight crews was inconsistent with risk of VRS to the V-22**
- b. Although the current 800 fpm/80° nacelle flight limitation may offer adequate safety margin, the envelope, warning signs and flight characteristics of V-22 VRS are still not well defined**
- c. Night formation flight approaches require inter-aircraft coordination, especially during early nacelle conversion**
- d. If future operating limitations (following completion of flight test envelope definition) include a 40KIAS (or less) limit, then the V-22 airspeed indication system may not be adequate, as it is unreliable below 40KIAS**



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## **The Mirana Mishap and Vortex Ring State Potential Recommendations**

- a. Use the results of the planned High Rate of Descent flight tests to update/develop operating limitations, procedures, pilot training and incorporate a cockpit warning system.**
- b. Configure the pilot simulator with the capability to provide VRS training to the max extent possible based upon model limitations and information available. At a minimum include avoidance training**
- c. If testing indicates poor aerodynamic warning, the aircraft should be configured with a cockpit warning system. Consider the following as potential inputs to warning system**
  - 1) Airspeed / sink rate combination based on demonstrated envelope with appropriate margin**
  - 2) proprotor instrumentation**
  - 3) aerodynamic precursors**
- d. If flight test indicates need for airspeed envelope flight limitation of 40 KIAS or less, the Program should procure or develop a more accurate airspeed indicator**
- e. V-22 Program (NATOPS Model Manager) should develop procedures for inter-aircraft coordination during formation decelerating conversions**



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## **OPEVAL Crew Qualifications Discussion**

- **Press accounts and OPEVAL mishap family concerns that operational pilots were improperly placed into test environment**
- **OPEVAL and Developmental Test (DT) have different requirements for aircrew**
- **DT requires contractor or military experimental and engineering test pilots**
- **OPEVAL test requires highly qualified aircrew with recent operational experience**
  - **Records show rigorous selection process (6 selected out of 120 pilot applicants)**
  - **HMX-1 training syllabus and flight assignment procedures were complete and complied with**
- **Policy prohibits OPEVAL pilots from participating in development testing (one exception was formally approved during DT based on low-risk for that particular flight)**
- **Part of the public perception problem may be the concern by the public that the V-22 Program unfortunately learned a DT lesson during operational testing (VRS mishap)**



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## **OPEVAL Crew Qualifications Potential Conclusions**

- a. The process for crew selection, training and assignment to V-22 OPEVAL test flights was reasonable and consistent with longstanding policy.**
- b. By its nature, early OPEVAL flights are characterized by a level of risk higher than that of fleet operations (thus the requirement for experienced crews), but less than that of development test phase.**



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## **OPEVAL Crew Qualifications Potential Recommendations**

- a. As the testing program proceeds, test managers (contractor, NAVAIR, and operational) should continue to pay special attention to selection and assignment of flight crew members.**
- b. Based on experience so far, it appears prudent that as NAVAIR continues to develop and test the V-22, they should take all reasonable steps to ensure that OPEVAL aircrews are not subjected to undue risk by thoroughly assessing all known and suspected high risk flight regimes.**
- c. Until aircraft is ready for deployment, restrict flying with non-essential personnel. Assess Operational Risk Management factors before clearing increased risk flights or flight maneuvers (e.g.. OPEVAL assaults, night flying, emphasize compliance with night and weather currency requirements)**



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## **MV-22 Aircrew Flight Training Discussion**

### **MV-22 Training and Readiness manual (T & R)**

- **Provides template for standard MV-22 units/Programs of Instruction for basic, transition and refresher pilots as well as a modified refresher syllabus and instructor syllabus**
- **Defines squadron core capability/basic aircrew qualification requirements/required sorties to maintain core skills**
- **Integrated Multi-media Instruction (IMI)/Simulators**
  - **IMI is a quantum leap over previous USMC ground training tools.**
  - **Full flight simulator (FSS) is state of art, FAA level D simulator. Fully networkable with other FSSs and with Flight Training Devices (FTDs)**



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## **MV-22 Aircrew Flight Training Discussion**

- **Squadron Standardization Manual/V-22 Naval Aviation Training and Operating Procedures Standardization (NATOPS) Manual/Tactics Manual**
  - **All undergoing modifications/updates/re-writes normal for this stage in aircraft fielding (next NATOPS change has over 1000 changes)**
- **Although money has been programmed for upgrades to both the IMI and simulators; DoD funding in this area has traditionally suffered from instability and inadequacy**



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## **MV-22 Aircrew flight Training Possible Conclusions**

- a. The MV-22 Aircrew flight training syllabi and their integration with ground training and simulator flights have been well thought out and documented.**
- b. The IMI ground training and Full Flight Simulators are state of the art.**
- c. Although adequate now, historical precedent suggests funding may not remain stable throughout upcoming budget cycles.**
- d. The MV-22 Standardization Manual adequately addresses flight standardization within VMMT-204.**
- e. At this early stage in it's development the relatively large size of the V-22 NATOPS Manual is considered consistent with the fact that the V-22 is a complex aircraft and is the first operational tiltrotor aircraft.**
- f. The MV-22 NATOPS Manual is undergoing the same developmental growth experienced by previous NATOPS Manuals, however, because of the challenges currently facing the MV-22, extraordinary effort ought to be placed on the NATOPS Manual so that it reaches the necessary level of maturity before training resumes**



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## **MV-22 Aircrew flight Training Possible Recommendations**

- a. Ensure adequate funding is provided for aircraft simulator maintenance and upgrades**
- b. Complete updates to MV-22 NATOPS, Standardization and Tactics Manuals to support pilot/squadron transition and re-currency training.**
  - verify procedures with the VMMT-204**
- c. Prior to first operational flight, convene an out-of-cycle NATOPS manual conference to assure consistency and adequacy of Emergency Procedures & Operational limits**
  - Develop an expeditious process to incorporate changes that come from this conference and from ongoing test and evaluation**



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## **Downwash Concerns Remote Area Operations Discussion**

- **OPEVAL Report identified downwash effects as a major deficiency to successful deployment of the aircraft (Nighttime Night-Vision-Device desert landing brownout)**
- **Desert/remote area operations historically are the most demanding/challenging for aircrew.**
  - **Shifting topography, varied soil composition, changing illumination effects**
  - **The Services have developed Tactics/Techniques and Procedures to be utilized to safely operate in the desert at night with Night Vision Devices.**
- **Discussion with OPEVAL aircrews (USMC and USAF) yielded variety of opinions on level of the risk (and potential to address successfully with techniques and procedures).**
- **V-22 Incorporates latest in night Vision-Device-technology including latest generation of Night Vision Goggles (ANVIS-9), a Night Vision Goggle Head Up Display, and Forward Looking Infra-red Radar, all of which mitigate brownout risk.**
- **The V-22's extended range provides greater ability to reach acceptable landing zones (reduce brownout potential).**



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## **Downwash Concerns Remote Area Operations Possible Conclusions**

- a. The V-22 has greater downwash than most helicopters**
- b. The V-22 is configured with enhanced Night Vision Device capability and has the range to reach a far greater number of landing zones than a helicopter.**
- c. Testing in a desert environment to date has been insufficient to fully develop appropriate techniques and procedures.**



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## **Downwash Concerns Remote Area Operations Potential Recommendations**

- a. The services should continue to develop procedures and techniques for the high downwash “desert brownout” situation.**
- b. The resultant procedures and techniques should then be included in the training manuals and training syllabus.**
- c. Tactical unit night operations in landing sites that have the potential for brownout should be restricted until procedures and techniques are developed.**



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## **Downwash Concerns Personnel Deployment/Recovery from In Ground Effect/Out of Ground Effect Hover Discussion**

- **The Joint Operational Requirements Document (JORD) for the V-22 requires that the aircraft have the capability to employ:**
  - **Two fast ropes off the ramp and one out the cabin door (threshold)**
  - **Fast rope insertion/extraction system, stabilized extraction rigging, and rope ladders through both the ramp and cabin door (threshold/USSOCOM)**
- **Based on poor Developmental Test performance, the V-22 Program does not believe that fast roping/rappelling operations from the cabin door is an option worth pursuing and has recommended that the JORD be changed to reflect an alternative location.**
- **Special Patrol Insert/Extraction (SPIE) missions (aft cargo hook hole ) and the rappel mission (aft cargo hook hole and ramp) were executed satisfactorily.**
- **The V-22 was “assessed as having the capability to meet the JORD requirement for helocast by traditional techniques under daylight conditions”. Night helocast was not accomplished because of the lack of a coupled hover capability**
- **Lack of rope ladders or a suitable hoist precluded the evaluation of Special Operations Forces over-water-recovery.**



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## **Downwash Concerns Personnel Deployment/Recovery from In Ground Effect/Out of Ground Effect Hover Possible Conclusion**

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- a. The concept of personnel deployment from a hovering V-22 has been partially demonstrated.**
- b. Several JORD requirements in this area remain to be demonstrated, and tactics, techniques and procedures need to be developed.**



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## **Downwash Concerns Personnel Deployment/Recovery from In Ground Effect/Out of Ground Effect Hover Possible Recommendations**

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- a. The services should revalidate the requirements for Personnel Deployment and Recovery operations.**
- b. If these requirements remain valid then these systems should be incorporated in to the aircraft as soon as possible.**
- c. Follow-on testing and evaluation is required to address tactics, techniques and procedures to be utilized in the conduct of Personnel Deployment and Recovery operations.**



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## **Downwash Concerns External Load Operations Discussion**

- **The OPEVAL report did not identify downwash as an issue during external load operations.**
- **Evaluation states that while external load operations were possible, “they remain a significant challenge.”**



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## **Downwash Concerns External Load Operations Possible Conclusions**

- **While external load capability was demonstrated during OPEVAL, downwash effects on ground personnel may be a challenge to its successful introduction to tactical operations.**



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## **Downwash Concerns External Load Operations Possible Recommendations**

- **Follow On Test & Evaluation should be conducted to further refine tactics, techniques and procedures ensuring that external load operations can be conducted safely and effectively.**



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## V-22 Autorotation Discussion

- **There are two specific situations in which the V-22 may be required to autorotate:**
  - **A dual engine failure while in conversion (helicopter) mode**
  - **The loss of a single engine coupled with an Interconnect Drive Shaft (ICDS) failure in conversion (helicopter) mode**
- **The Program has determined that the risk of a dual engine failure or a single engine failure with an ICDS failure would be improbable.**
- **The Program has indicated that the probability of a single engine failure coupled with an ICDS failure is two orders of magnitude greater than the probability of the aircraft having a dual engine failure.**
- **While there are emergency procedures established in NATOPS for dual engine failures there are no procedures that address the loss of one engine with the subsequent loss of the ICDS.**
- **Additionally, NATOPS emergency procedures call for conversion to Airplane mode after loss of an engine, they then suggest landing in VTOL mode. there is no one-engine-inoperative precautionary (glide) landing procedure. This leaves the pilot vulnerable to autorotation should the operating engine or ICDS fail on final.**



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## V-22 Autorotation Discussion

- **During V-22 Developmental Test autorotative descents were conducted in the aircraft and autorotations to a landing conducted in the simulator.**
- **V-22 demonstrated stable autorotative descents in flight test and offered enough control to the pilot to touchdown at a survivable rate of descent.**
- **Evaluations in the simulator have shown limited repeatability of making a safe landing at the touchdown phase.**
- **While autorotations are problematic for the V-22 it has been demonstrated through testing and simulation that power off glides in the airplane mode can be successfully executed to a hard surface runway as performed in other fixed wing aircraft having similar glide characteristics.**



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## V-22 Autorotation Discussion

- **The probability of the V-22 being forced to execute an autorotation vice a power-off glide is considered low**
  - **Employment concept; 70% Fixed Wing and 30% Rotary Wing**
  - **Design characteristics; high reliability engines, engine separation, vulnerability features, lack of tail rotor**
  - **Emergency Procedures training (go to Airplane mode after first failure)**
- **V-22 Crashworthiness features are designed to maximize the potential for occupant survivability should a crash landing occur.**



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## **V-22 Autorotation Possible Conclusions**

- The V-22 has limited autorotational capability**
- b. That the V-22 possesses even some ability to autorotate sets it apart from fixed wing aircraft.**
- c. That it possesses the ability to conduct a survivable power off glide landing sets it apart from all helicopters.**
- d. There are no emergency procedures in NATOPS for a single engine failure coupled with an ICDS failure, a situation that would require a power off glide landing or an autorotation.**
- e. The V-22 community does not appear to place enough emphasis on the glide landing capability of the aircraft as an alternative to autorotation, especially in the one-engine-out procedures.**
- f. Employment concept, design features and pilot training will limit the probability of an autorotation having to be conducted.**
- g. Crashworthiness features significantly enhance survivability over that of legacy platforms.**



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## **V-22 Autorotation Possible Recommendations**

- a. The Services should reassess the requirement for autorotative flight in view of the low probability of improvement and the existence of alternatives.**
- b. Assess the feasibility of safe landing with the combination of engine and ICDS failure, and incorporate appropriate procedures in the NATOPS and training syllabus if necessary.**
- c. Re-assess the capability of the V-22 to conduct power-off glides. Explore design and operational techniques to optimize power-off glide capability (e.g. minimize proprotor drag commensurate with auxiliary power requirements)**
- d. NAVAIR ensure that the full flight simulator used by pilots at MCAS New River accurately emulates both autorotative and power off glide simulations to the degree required for effective pilot training.**



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## **Safety Implications of the Tiltrotor Concept Discussion**

- **In none of the five major tiltrotor mishaps since 1991 (XV-15 and V-22) was tiltrotor technology found to be a cause factor, however, three of them included tiltrotor unique roll response to initial failure**
- **Tiltrotor unique hazards constitute less than 6% of all system safety risks**
- **Tiltrotor unique safety challenges**
  - **Poor autorotation performance (high disc loading)**
  - **Propensity for rapid development of high sink rate (high disc loading)**
  - **Roll response to VRS, or other asymmetric proprotor conditions in VTOL mode**
  - **High downwash velocity**
- **Tiltrotor unique safety enhancements**
  - **Low chance of having to do an autorotation**
    - **Low vulnerability (speed, range, engine placement)**
    - **Ability to convert to airplane mode (and potentially precautionary glide landing) after first engine failure**
    - **No tail rotor**
  - **Good field of view for pilots during decelerating transition (nacelle angle, not fuselage angle, used to slow the aircraft)**
  - **Promise of good sink rate margin (VRS avoidance)**



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## **Safety Implications of the Tiltrotor Concept Potential Conclusions**

- a. Tiltrotor technology introduces several safety related challenges as well as safety enhancements to medium lift mission.**
- b. When considered in total, tiltrotor unique risks do not appear to be insurmountable, nor to outweigh the enhancements.**
- c. All tiltrotor unique risks appear to be manageable through design modifications and operational procedures and techniques**



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## **Safety Implications of the Tiltrotor Concept Potential Recommendations**

- a. Continue to develop mitigation strategies to limit the potential for autorotation and the risk of asymmetric thrust conditions**
- b. Specific recommendations are included in the VRS, downwash and autorotation issue briefs**



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## System Safety Program Discussion

- **The V-22 System Safety Program is managed by a system safety professional with adequate Bell Boeing support and extensive experience on the program**
- **The Program complies with appropriate system safety standards**
- **The System Safety Program is appropriately integrated into Program risk management and decision making**
- **The V-22 Program categorizes risks in a manner that is more conservative than recently published probabilistic frequency definitions (single engine failure and dual engine failure are in same risk category RAC 1D)**
- **The number of high and medium risk issues closed out by the program (risks accepted) is considered by NAVAIR System Safety Management as reasonable compared to other ongoing aircraft programs and programs at this stage of development**
- **Before OPEVAL, NAVAIR conducted a flight readiness review, and the Program got a “Go” from System Safety**
- **NAVAIR grounding is currently in effect as result of latest mishap and System Safety is part of that process**



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## **System Safety Program Potential Conclusions**

- a. The V-22 System Safety Program is appropriately staffed and engaged**
- b. The number and type of risk issues being tracked by the program do not appear to be abnormal for an aircraft at this stage of development**
- c. The V-22 program uses an overly conservative standard to define risk level for its various safety issues: the result is that the risk level categories by themselves are of limited use to the decision maker in safety risk mitigation trades**



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## System Safety Program Potential Recommendations

- a. NAVAIR should develop a consistent approach to measuring overall risk level in development programs to aid the program in risk trades and other decision making, NAVAIR in the flight readiness review process, and DOD in its acquisition decisions; consider more use of probabilistic risk techniques**



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## DOT&E Safety Issues Discussion

- **DOT&E briefing listed over 175 individual deficiencies during OPEVAL as safety issues or as having safety implications (many were repeats of same discrepancy, i.e.: hydraulic leaks)**
- **Many of the safety items referenced in the DOT&E briefing appeared to be relatively minor hydraulic system reliability issues (i.e. servicing fluid level problems and minor leaks)**
- **related issues, so the Panel was concerned that their more recent analysis may have uncovered safety issues not previously known by the program**
- **Lack of risk level categorization in DOT&E assessment limits usefulness of their safety analysis (report or briefing) in understanding relative risks**
- **NAVAIR analysis of DOT&E briefing showed no new safety issues and 15 generic issues covered by existing Safety Action Records. Remainder of DOT&E safety related concerns were either low risk, or related more to reliability, availability and maintainability than to safety**



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## DOT&E Safety Issues Potential Conclusion

- **Although at least one new safety issue (VRS) came out of the OPEVAL, there were no new safety issues, nor changes in V-22 hazard risk level assignments as a result of the DOT&E analysis of OPEVAL**



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## **DOT&E Safety Issues Potential Recommendation**

- **To aid the decision makers, DOT&E and OPTEVFOR should consider use of standard risk indices (i.e. Risk Assessment Codes) when reporting on safety issues**



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# Quality Control Discussion

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- **Background**
  - **Program suffered from production quality problems at the beginning of Low Rate Initial Production (LRIP)**
  - **Quality improvement initiatives steadily reduced number of defects**
    - **Quality performance in 2000 was greater than 35% better than in 1999 (Delivered aircraft defects noted by customer)**
    - **Quality Management documents at Amarillo show discrepancies reduced from ~155 to ~65 per ship (between ships 11 and 20)**



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# Quality Control Discussion

- **Quality Control Issues**
  - **Listings of top Fleet Readiness “Downgraders” indicate a continuous need for close attention to quality control measures. Items identified are tracked weekly and specifically focused teams are appointed to address deficiencies**
    - **Click Studs (used to secure items, e.g. mounting brackets)**
      - Problem: Improper bonding causes mounting failures and inconsistent location
      - Solution: Tighter installation tolerances, procedures & adhesives
    - **Pitch Link Rod-End Bearings**
      - Problem: Excessive axial play exceeds flight tolerances
      - Solution: Revised bevel on rod-end bearing and added coating
    - **Non-standard manufacturing**
      - Problem: Unique drilling and trimming of panels prevent interchangeability
      - Solution: 3D models created and laser targeting system added to fix mismatches
      - Problem: Wiring harness and hydraulic routing not in accordance with blueprints
      - Solution: Special training and inspections initiated, top-down engineering review addressed enhancements



Panel to Review  
the V-22 Program

## Quality Control Discussion

- **Quality Control Issues (cont)**
  - **Windows**
    - Problem: Flow-coating process creates distortions. Contours susceptible to temperature variation during manufacturing
    - Solution: Flow-coating was too thick (reduced). Manufacturing parameters controlled and source inspections to provide quality control before issuing to user
  - **Blade Fairings**
    - Problem: Blade fold wing stow process would break blade fold fairing panels
    - Solution: Fairing design and tooling modified
  - **Each Readiness “Downgrader” identified has a team appointed to and process established to address deficiencies and recommendations**
  - **All “downgraders” have active corrective actions in-place or under review**
- **Tiger Team preliminary indications point to new quality issues (some hardware configuration variations between aircraft and some deviations from blueprint)**



Panel to Review  
the V-22 Program

## Quality Control Possible Conclusions

- **Bell-Boeing, V-22 Program Manager, Defense Contract Management Agency, and the end-user appear to pay close attention to quality control measures.**
  - Each item identified is actively addressed until solutions are in-place
  - Quality metrics and tracking was evident throughout both contractor production facilities
  - Bell and Boeing both have good quality process improvement programs ongoing
- **effective medium for identifying and focusing management attention on quality issues**
- **Tiger Team preliminary indications about quality variations among nacelles are a concern to be carefully addressed**



Panel to Review  
the V-22 Program

## **Quality Control Possible Recommendations**

- a. Take appropriate action to resolve Tiger Team findings**
- b. Continue improvements to Contractor, DCMA and Service quality processes**



Panel to Review  
the V-22 Program

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## **V-22 Program Issues**

# **Combat Effectiveness**



Panel to Review  
the V-22 Program

## Reliability and Readiness Discussion

- **OPEVAL results were mixed with respect to reliability and availability metrics**
- **Low Mean Time Between Failure (MTBF) highlighted by operational testers**
- **Poor reliability, especially in hydraulics systems, was major contributor; late change in test metric (MFHBF) contributed to poor results;**

<i>Measure</i>	<i>USMC Requirement</i>		<i>Entire MV-22</i>	
	<i>Threshold</i>	<i>Objective</i>	<i>OPEVAL (804 flt hrs)</i>	<i>Since Feb 22 (540 flt hrs)</i>
<b>MFHBA</b>	≥ 17.0 hours	N/A	<b>13.9 hours</b>	<b>17.0 hours</b>
<b>MR</b>	≥ 85%	N/A	<b>81%</b>	<b>85%</b>
<b>MFHBF*</b>	≥ 1.4 hours	2.0 hours	<b>0.6 hours</b>	<b>0.7 hours</b>
<b>MC</b>	≥ 82%	≥ 87%	<b>46%</b>	<b>57%</b>

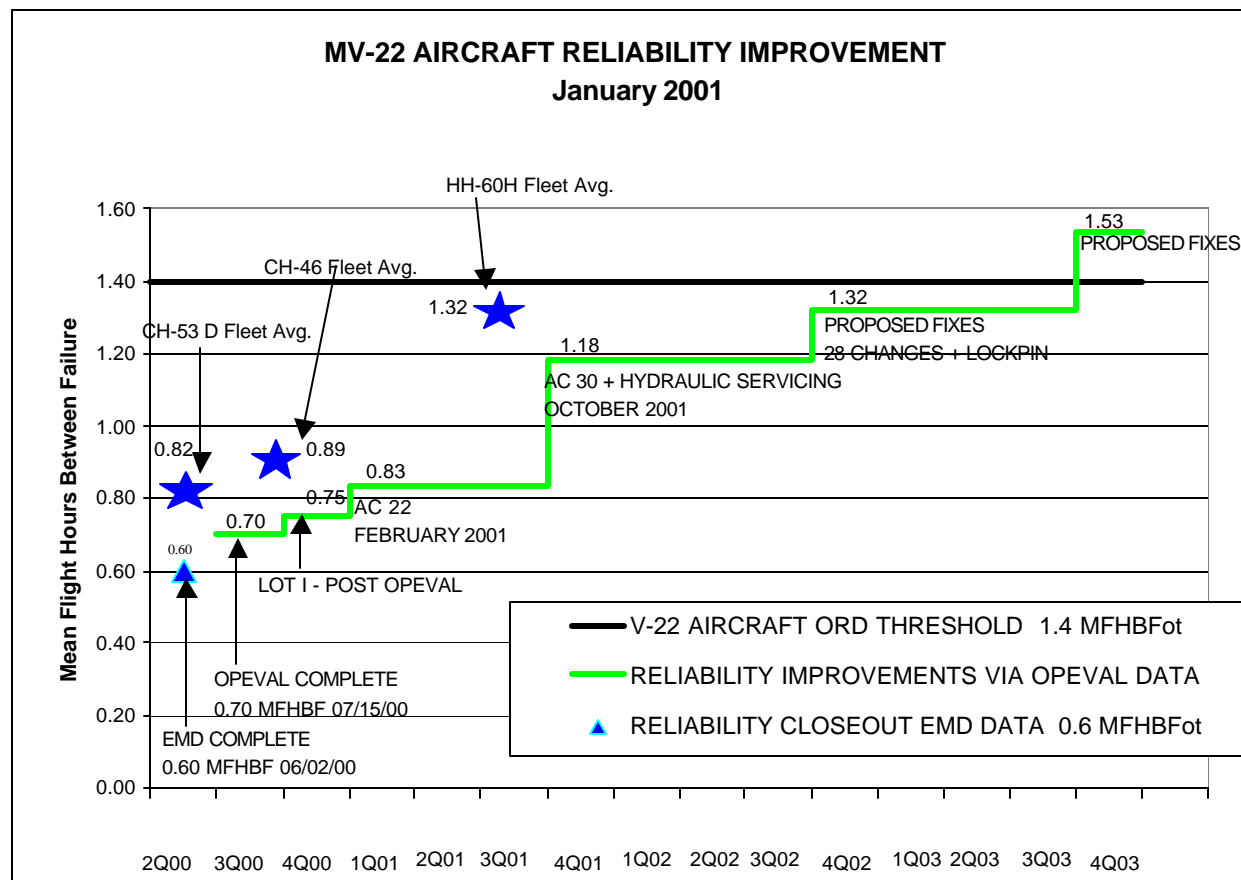
\* Original JORD threshold was 1.4 MTBF (equivalent to ~1.1 MFHBF)

- **January program plan called for reliability upgrades that are intended to exceed 1.1 MFHBF by end of 2001, and 1.4 MFHBF by end of 2003**
- **MTBF and MFHBF: failure is defined as any failure (an engine counts the same as a light bulb for this measure)**



Panel to Review  
the V-22 Program

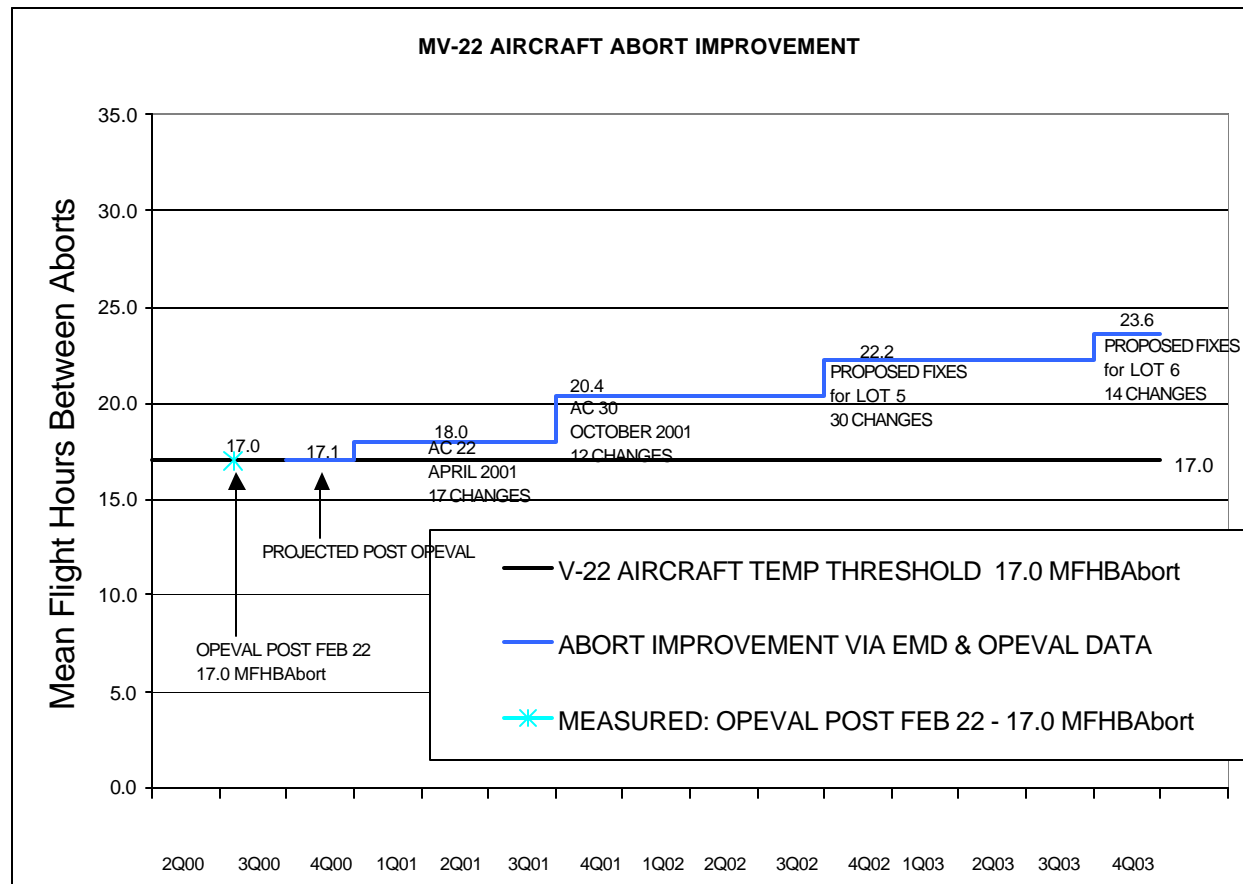
## Reliability and Readiness





# Reliability and Readiness

Panel to Review  
the V-22 Program





Panel to Review  
the V-22 Program

## Reliability and Readiness Potential Conclusions

- a. The operational availability of the V-22 , as demonstrated in the OPEVAL is not adequate. However, it is not clear that the Mean Time (or Flight Hours) Between Failure is as important to the users as Mean Time Between Aborts, which was adequate during the test.**
- b. The plan to meet the threshold for MFHBF includes improvements to the hydraulic system, and shows late 2003 as the time when the the requirement should be met.**
- c. With no apparent service need change, the MTBF requirement was effectively changed to a stricter standard late in development, well after the final design for LRIP**
- d. Contractor component reliability predictions during early design and development were substantially better than demonstrated results during OPEVAL**



Panel to Review  
the V-22 Program

## Reliability and Readiness Potential Recommendations

- a. The Services should revalidate the threshold reliability requirements consistent with relevant reliability requirements drivers.**
- b. DoD and the contractors should improve their reliability prediction models and processes**
- c. Review the reliability improvement plan and prioritize deficiencies to insure that funding is applied in prioritized sequence**
- d. Reassess relevance of current reliability and maintainability measurements**
  - a. Prioritize use of resources for resolution of reliability and maintainability shortfalls**
  - b. Emphasize Mean Flight Hours Between Abort (MFHBA) and Mean Maintenance Hours per Flight Hour as primary metrics**



Panel to Review  
the V-22 Program

## Maintainability and the Nacelle Discussion

- **Several factors make maintenance and inspection of the nacelle hardware very difficult:**
  - tight quarters,
  - poor inspection access,
  - inadequate access panel fasteners,
- **Other factors that add to the maintenance challenge with the nacelle are:**
  - lack of consistent configuration from one airframe to the next (covered by Quality issue brief)
  - the high failure rate of the click studs (covered in reliability section of this report),
  - poor maintenance publications (covered by Integrated Electronic Technical Manual (IETM) issue),
  - normal operational issues that apply to all types of aircraft (poor lighting, weather conditions, oil, dust, etc.).



Panel to Review  
the V-22 Program

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## Maintainability and the Nacelle Potential Conclusion

- **The tight spacing of critical hardware, lack of adequate quick access and poor reliability of fasteners on remaining access panels combine to make the nacelle a maintainability challenge. The effect, at best, is high maintenance man-hours, and, at worst, missed critical failure precursors.**



Panel to Review  
the V-22 Program

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## **Maintainability and the Nacelle Potential Recommendations**

- a. Investigate the possibility of providing more quick access panels for the maintainers, and to evaluate high reliability alternatives to the Mini-Mark fastener.**
- b. Investigate the feasibility of a nacelle redesign to improve the spacing/protection/of critical components, maintenance working space, access and the overall maintainability of this critical aircraft area.**
- c. Include in any nacelle redesign the potential for user-friendly inspection capability for components that are exceptions to the flight controls system redundancy requirement and other critical components (i.e. borescope access, more easy access panels, etc.)**



Panel to Review  
the V-22 Program

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## **Viability of IETM for the V-22 Discussion**

- **The Integrated Electronic Technical Manual (IETM) was designed to be an interactive Database that would allow maintainers utilizing a portable electronic display device the ability to reference all of the maintenance publications and configuration data for each aircraft in a squadron.**
- **It has the potential to be integrated with both aircraft health monitoring system and service readiness reporting systems.**
- **New software drops are done every 45 days**
- **The hardware system (laptop) is easily transportable and deployable.**



Panel to Review  
the V-22 Program

## Viability of IETM for the V-22 Discussion

- **The Integrated Electronic Technical Manual (IETM), as currently fielded, fails to meet the needs of the maintenance personnel in VMMT-204; examples include:**
  - **Incomplete data**
    - **No Integrated Parts Breakdown**
    - **No mirror image graphics for multiple systems**
    - **No schematics for fuel, hydraulic or electrical systems**
  - **Inaccurate maintenance procedures**
    - **Numerous tasks are documented under the wrong system/subsystem listing**
    - **Erroneous torque values**
    - **Inconsistent part number references**
  - **Poor organization of data and procedures, and lack of clarity**
    - **Non-user-friendly navigation through the system**
  - **Poor integration of logistics support**
    - **V-22 only aircraft using Universal Numbering System (UNS) vice the Work Unit Code (WUC) logistics numbering system**
    - **No technical or support manuals available for UNS**
  - **Contractor validation of IETM completed August 1999 ( 85% was by simulation and table top review, and 15% on actual aircraft, this data is consistent with previous validation processes)**
  - **Bell Boeing verification support was contracted and subsequently descoped to reallocate funding elsewhere on the program**
  - **Full organizational verification by Government planned for 4th Qtr FY01**



Panel to Review  
the V-22 Program

## **Viability of IETM for the V-22 Possible Conclusion**

- a. As currently fielded, IETM fails to meet the needs of organizational maintenance**
- b. IETM hardware and supporting software is immature and developmental in nature**
- c. Significant development and testing needs to be accomplished before IETM is ready for Fleet introduction.**
- d. Verification of IETM needs to be accomplished as soon as possible.**
- e. Based on field performance to date, it appears that technical publication validation was inadequate**
- f. Of greater concern is the fact that the V-22 program is the only program using UNS. All other programs use WUC. This will create long-term difficulties because the V-22 program will be required to maintain this unique system. Additionally, when deployed the V-22 will be incompatible in this respect with the rest of the inventory**



Panel to Review  
the V-22 Program

## **Viability of IETM for the V-22 Possible Recommendations**

- a. The V-22 Program should expeditiously assess the options for V-22 technical publications (electronic and paper)**
- b. Significant development and testing should be accomplished prior to operational deployment**
- c. Provide adequate developmental support to the squadron for the selected system**
- d. Review the adequacy of contractor completed validation process in light of operational deficiencies and heavy reliance on simulation**
- e. Verification of IETM should be accomplished as soon as possible.**
- f. Address standardization, testing and funding requirements for Electronic Technical Manuals across all platforms and services.**
- g. The program should take immediate steps to transition from UNS to the standard WUC logistics system**



Panel to Review  
the V-22 Program

# **Utilization of Optimized Naval Aviation Logistics Command Management Information System (NALCOMIS) by VMMT-204 Discussion**

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- **omate its  
aviation maintenance environment. It was designed to:**
  - **Report maintenance transactions in near real-time.**
  - **Track actual aircraft configuration data.**
  - **Locate parts and material through connectivity with supply departments**
  - **Allow instant access to readiness by authorized users**
  - **Maintain electronic log books and interface with aircraft diagnostic systems**



Panel to Review  
the V-22 Program

## **Utilization of Optimized NALCOMIS by VMMT-204 Discussion**

- **Navy leaders have identified that significant drops in reported readiness rates accompany the transition from NALCOMIS to Optimized NALCOMIS**
- **Line organizations are currently unable to quantify the new readiness numbers relative to the CNO's established MC and FMC readiness goals (squadrons have to report using both legacy and new system).**
- **OPTEVFOR has recently recommended withdrawal of certification of system for Follow On Test & Evaluation (FOT&E) and to discontinue fielding**
  - **mission failures**
  - **training inadequacies**
  - **data transfer integrity**



Panel to Review  
the V-22 Program

## **Utilization of Optimized NALCOMIS by VMMT-204 Discussion**

- **VMMT-204, the first USMC squadron to employ Optimized NALCOMIS, reports following**
  - **H while the Fleet**
  - **Marine Force only has access to the 4790.G**
  - **The system allows errant work orders to be transmitted**
  - **Lack of system reliability forces all documentation to be backed up manually**
  - **The system does not currently interface with either the aircraft diagnostic system or IETM**
  - **No contingency exists to fly or fix aircraft if the new system goes hard down. No paper copies of records exist outside of the database.**



Panel to Review  
the V-22 Program

## **Utilization of Optimized NALCOMIS by VMMT-204 Possible Conclusion**

- a. NALCOMIS (Optimized) is experiencing a high number of deficiencies in the squadron environment**
- b. Baseline data for NALCOMIS (Optimized) has not yet been developed to properly evaluate performance of reporting units**
- c. Inclusion of NALCOMIS (Optimized) with draft documentation in VMMT-204, as it faced the requirement to field a new aircraft without verified maintenance publications, coupled with an immature IETM, clearly complicated the challenge**



Panel to Review  
the V-22 Program

## **Utilization of Optimized NALCOMIS by VMMT-204 Possible Recommendations**

- a. NAVAIR should correct the deficiencies and incompatibilities that are resident in the NALCOMIS Optimized system as soon as practicable**
- b. NAVAIR should provide a set of guidelines and metric algorithms to all organizations who use NALCOMIS readiness data for planning, budgeting and other resource decision-making.**
- c. VMMT-204 should be given careful consideration in any deliberations concerning OPTEVFOR decertification recommendation**



Panel to Review  
the V-22 Program

## **V-22 Maintenance Training System Discussion**

- **1996 DoN invested \$41M with Bell/Boeing for development and procurement of a Naval Aviation Maintenance Trainer Suite (NAMTS)**
  - **4 composite maintenance trainers (CMT) and**
  - **4 composite maintenance procedures (CMPT) trainers**
  - **Designed to replicate 1335 maintenance tasks.**
  - **Reflectone was selected as contractor. Work stopped in 1997. No-fault mutual rescission was signed in May 2000.**
- **Bell/Boeing and PMA-205 (the Program Manager for aircraft training devices) agreed that with the remaining \$14M low fidelity part task trainers would be built and that separate contracts would be let for an Integrated Multi-media Instruction (IMI) suite and high fidelity CMTs.**



Panel to Review  
the V-22 Program

## **V-22 Maintenance Training System Discussion**

- **Boeing estimate of \$130M for CMTs resulted in cancellation and decision to use actual aircraft in place of CMTs.**
- **Current system consists of IMI, Part Task Trainers, and actual aircraft. System is expected to be in place and functional by September 2001.**
- **Advantages of actual aircraft as maintenance trainers**
  - **Actual aircraft have a higher physical and functional fidelity**
  - **The maintenance of the trainers will mirror that of operational aircraft**
  - **Ground support equipment will not have to be modified**
  - **Spares will be available through the supply system**
  - **Hardware and software configuration can be simplified through the utilization of the ECP process**



Panel to Review  
the V-22 Program

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## **V-22 Maintenance Training System Discussion**

- **The disadvantages of utilizing actual aircraft as maintenance trainers are:**
  - **Additional ground support equipment will be required to be purchased, maintained and supported by the Fleet Replacement Enlisted Skills Training (FREST) unit**
  - **Aircraft components are not designed to withstand the multiple remove and replace cycles required for training and the associated cost and quantity of spares may be excessive and must be planned and budgeted for**



Panel to Review  
the V-22 Program

## **V-22 Maintenance Training System Possible Conclusions**

- a. Until adequate maintenance training systems are in place, the loss of the Naval Aviation Maintenance Training System will have an impact on the capability of both VMMT-204 and the Fleet Replacement Enlisted Skills Training unit to accomplish their missions of training pilots and maintainers.**
- b. The three systems being procured should adequately address this deficiency if they are properly funded and supported.**
- c. The capability offered by Integrated multi-Media Instruction to train maintainers is state of the art.**
- d. There are both advantages and disadvantages to use of actual aircraft as maintenance trainers.**
- e. To be effective, aircraft maintenance trainers must be properly funded for spares and fleet modifications**
- f. The disadvantages of using an aircraft as a maintenance trainer outweigh the advantages and complicates the maintenance training for the other services**



Panel to Review  
the V-22 Program

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## **V-22 Maintenance Training System Possible Recommendations**

- a. Retrofit and modification of maintenance training aircraft (when appropriate) must occur at the same time or prior to those changes being incorporated in tactical aircraft.**
- b. Funding for training aircraft spares must be adequately budgeted.**
- c. Consider the eventual replacement of the aircraft being used as maintenance trainers with appropriate maintenance trainers.**



Panel to Review  
the V-22 Program

## V-22 Diagnostic Capability Discussion

- **The V-22 Operational Requirements Document requires that the aircraft have a Data Storage System (DSS) able to accommodate the downloading of maintenance data in 15 minutes or less to support maintenance debriefings, allow the rapid sorting and correlation of data points, and provide effective guidance for maintenance personnel.**
- **OPEVAL results stated V-22 Diagnostic system demonstrated the capability to be adequate, reliable and accurate.**
- **During OPEVAL both fault detection and fault isolation performed well and exceeded their threshold and objective values, but false alarm failed by a large margin.**



Panel to Review  
the V-22 Program

## V-22 Diagnostic Capability Discussion

- **Program Office has a false alarm reduction plan and is working on software fixes for the Aircraft Maintenance Event Ground Station (AMEGS), JVX Application Software System (JASS), and the development of diagnostic file filters, hardware changes, and subsystem software updates that have less propensity to trigger false alarms.**
- **AMEGS displays six figure Hex fault isolation codes which do not correspond to the Universal Numbering System (UNS) codes utilized by maintenance troubleshooters.**
- **The DOT&E report identified that the utility of the Built-In Test (BIT) systems was reduced by the lack of integration between the AMEGS/VSLED/IETMS/NALCOMIS. Each stand-alone system required manual transfer of common data elements from one system to another.**



Panel to Review  
the V-22 Program

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## **V-22 Diagnostic Capability Possible Conclusion**

- a. The current plan to reduce the V-22 false alarm rate is too slow**
- b. The AMEGS promises to be a powerful diagnostic tool for the maintainer, but the marginally integrated AMEGS, IETMS and NALCOMIS systems create undue workload in identifying and understanding system performance and maintenance issues.**



Panel to Review  
the V-22 Program

## **V-22 Diagnostic Capability Possible Recommendations**

- a. Expedite the plan to reduce the V-22 false alarm rate in both the aircraft and ground systems with priority on aircraft software**
- b. Take immediate steps leading towards full integration of AMEGS, IETMs and NALCOMIS**
  - Fix AMEGS, IETMs and Optimized NALCOMIS. Afterwards integrate them**
  - Teach troops how to use AMEGS**
- c. In the short term, expedite software cross-references for AMEGS and IETMs**



Panel to Review  
the V-22 Program

## **V-22 Program Issues**

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# **Programmatics**



Panel to Review  
the V-22 Program

## **Lack of adequate Communications among NAVAIR, Bell/Boeing, and the Customer Discussion**

- **There appears to be a lack of communications by officials of all organizations (program, contractor) that results in inadequate awareness of some of the issues and concerns being raised by VMMT-204.**
- **Significantly, some members of VMMT-204 were unaware of whether or not their issues were being addressed. These are relatively experienced people during a stressful time. This lack of information leads to decreased confidence levels and rumors--they need to know what is going on**
- **The issues of concern related by squadron personnel covered three areas, the safety, reliability and maintainability aspects of the aircraft, the maintenance system, and enlisted maintenance training**



Panel to Review  
the V-22 Program

## **Lack of adequate Communications among NAVAIR, Bell/Boeing, and the Customer Discussion**

- **The Program Office and Bell/Boeing appear to be aggressively working to resolve the issues that have been addressed by VMMT-204**
  - Since the discussions with Bell/Boeing, visits by the Contractors have been completed, and 90 members of VMMT-204 will have visited both Contractor facilities on 18 April.
- **The Osprey Support Center at MCAS New River is also actively engaged in supporting the squadron. VMMT-204 gave the OSC high marks for the cooperation and support provided to them.**
- **However, the concern is that the Squadron is not being adequately informed of the status of relevant issues (particularly safety related issues) in a timely manner.**
- **The solution to this problem of inadequate communications can be addressed through the Osprey Support Center (OSC), but it would require a change in support philosophy that includes at least:**
  - higher level of management involvement among the OSC, Bell Boeing and NAVAIR
  - non-business-as-usual approach to technical feedback to the operators (closer to the type of interface common in a test environment than in an operational environment)



Panel to Review  
the V-22 Program

## **Lack of adequate Communications among NAVAIR, Bell/Boeing, and the Customer Possible Conclusion**

- a. Standard legacy reporting processes are properly being used, but appear to be inadequate to the expressed desires of the operators**
- b. There is not enough communication of engineering change activities from the engineering community to the operators, considering the state of the V-22 in its development and introduction**
- c. The OSC appears to be an appropriate vehicle to improve the communications flow, but**
- d. The management attention appears to be at too low a level, and the feedback for operational problems and their solutions is too limited and slow**



Panel to Review  
the V-22 Program

## **Lack of adequate Communications between NAVAIR, Bell/Boeing, and the Customer Possible Recommendations**

- a. The V-22 Program, in coordination with HQMC and VMMT-204, conduct a review of information flow requirements between V-22 Program, Bell/Boeing, and the Customer, and develop a funded plan to increase the responsiveness to operator needs.**
  - a. Attention needs to be given to meeting similar requirements for the Air Force and SOCOM during CV-22 introduction**
- b. V-22 Program and Bell/Boeing supplement the normal formal reporting to and from the Osprey Support Center with feedback to facilitate the exchange of information to the customer.**
- c. Both the government and Bell/Boeing should increase the management visibility of the Osprey Support Center and decrease the turn around time for relevant problem resolution status**
- d. Recommend Bell Boeing CEOs, V-22 PM and JPO get together monthly to discuss V-22 issues. The program needs senior management level attention**



Panel to Review  
the V-22 Program

## **The Joint Program and Systems Engineering Discussion**

- **50/50 Joint Program Bell and Boeing share work and split profit**
- **Joint Program Office collocated at Patuxent River manages Systems Engineering**
- **Integrated Product teams, Analytic Integration Teams, active risk management, and corporate memory all keys to systems engineering effort**
- **The V-22 Program makes use of the Risk Management approach for all decision making.**
- **V-22 Risk Management is well managed, personally led by the Program Manager, well connected to contractors and to systems engineering and system safety**
- **While the risk management program does not use quantitative analysis, its qualitative analysis is pervasive at all levels of management and throughout all disciplines**
- **Systems Engineering Trade Study Priorities (1993 EMD System Engineering Mgt Plan) put emphasis on aircraft performance and shipboard compatibility over reliability, maintainability and flying qualities**



Panel to Review  
the V-22 Program

## The Joint Program and Systems Engineering Possible Conclusions

- a. The Bell Boeing Joint Program Office is a critical feature in the V-22 contractor organization, especially as regards program integration**
- b. The systems engineering approach used by the V-22 government contractor team appears to be robust, well managed and staffed, in spite of what might normally be considered a non-optimal prime contractor arrangement.**
- c. An important ingredient in the V-22 Program's systems engineering effort is continuity among its key personnel.**
- d. The results of the OPEVAL are relatively consistent with the 1993 systems engineering trade study weighting priorities...*the aircraft performed as designed!***
- e. The V-22 Program risk management approach appears to be robustly supported by management, and unusually well-coordinated with other program activities. In spite of its minimal use of state-of-the-art quantitative risk assessment techniques, it appears to be better coordinated and managed than risk management systems found in other major programs.**



Panel to Review  
the V-22 Program

## The Joint Program and Systems Engineering Possible Recommendations

- a. As the program proceeds, both NAVAIR and the contractors **must** ensure a high level of continuity and corporate memory in its Integrated Product and Analytic Integration Teams, and key management positions.
- b. Constant attention must be paid by both the Navy and Bell Boeing JPO to the potential for lapses in systems engineering integration discipline as team members try to solve problems outside of established processes (i.e. directly with contractors)
- c. For the next phase of system and requirements reviews, engineering changes, and deficiency fixes, the Program should update its trade study priorities consistent with program priorities
- d. The V-22 Program should continue to investigate the feasibility of introducing state-of-the-art quantitative risk analysis methods into their system.
- e. The DSMC risk management course should use the V-22 Program risk management process as a benchmark example of how to incorporate risk based decision support into every day program management.



Panel to Review  
the V-22 Program

## AFFORDABILITY Discussion

- **from \$6.6B**  
**the previous year**
  - **Restored 523 production aircraft**
    - **425 for Marine Corps' MV-22**
    - **50 for SOCOM's CV-22**
    - **48 for the Navy's HV-22**
- **FY 2001 President's Budget is \$38.1B**
  - **FY 1997 inflation indices reduced total program by \$6B**
  - **FY 1999 Quadrennial Defense Review (QDR) reduced the program by 65 aircraft leaving:**
    - **360 for Marine Corps' MV-22**
    - **50 for SOCOM's CV-22**
    - **48 for the Navy's HV-22**
  - **Aggressive cost reduction efforts**
    - **Even though MV-22 production aircraft were reduced by 65 aircraft, average procurement unit cost was reduced from from \$87.9 million to \$67.4 million**



Panel to Review  
the V-22 Program

## **AFFORDABILITY Discussion**

- **Budget Execution**

- **FY 2000 procurement deferred two V-22 aircraft per year (over the life of the program) to remain within the budgeted dollars**
- **Planned FY 2001 procurement would require similar deferral due to:**
  - **Higher inflation rates (5% vice 2%) negotiated by Defense Contract Management Command**
  - **A reduction in the anticipated learning curve efficiencies; and**
  - **Increased work to be accomplished**
- **FY 2002 procurement deferral and reprogramming to RDT&E may be required to accommodate proposed program restructure within existing funds**



Panel to Review  
the V-22 Program

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## **AFFORDABILITY**

### **Possible Conclusions**

- a. Sliding aircraft to the outyears does not affect yearly near-term budget demands, however, total program procurement cost will increase**
- b. Higher production rates in the outyears, coupled with multi-year procurement, could offset additional cost of deferring aircraft to later years**



Panel to Review  
the V-22 Program

## **AFFORDABILITY**

### **Possible Recommendations**

- **Immediately reduce the production rate to a minimum and take that near-term money and apply it to the fixes identified in this report. Once fixes are developed, tested and implemented, capture them into the production line as early as possible.**
- **Concurrently, establish maximum rate, firm-fixed-price, multi-year procurement to recover program cost and schedule**



Panel to Review  
the V-22 Program

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## **FUNDING RESERVES**

### **Discussion**

- **V-22 program lacks funding reserves for unexpected contingencies during development**
- **Design maturity is effectively deferred by lack of contingency reserves**
- **Complex new class of aircraft requires higher level of reserves to cover uncertainties in maintenance and reliability**
- **Program's remaining budget reduced 5-7% annually by undistributed reductions**



Panel to Review  
the V-22 Program

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## **FUNDING RESERVES**

### **Possible Conclusions**

- a. Reserves have always been needed to address program unknowns**
- b. No reserves were provided during development and limited reserves in production**
- c. CV-22 development is not fully funded (\$97M) to the current estimate**
  - Reserves for contingencies do not exist**



Panel to Review  
the V-22 Program

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## **FUNDING RESERVES**

### **Possible Conclusions**

- a. Provide funding reserve to enhance program development**
- b. Provide additional program funding and a funding reserve to complete CV-22 development**
- c. Increase Production Reserves for Engineering Change Proposals**



Panel to Review  
the V-22 Program

## **CV-22 BLOCK 0 DEVELOPMENT FUNDING Discussion**

- **In 1994, the Deputy Secretary of Defense specified**
  - Navy would pay for MV-22 development and production and the CV-22 development with no cost limit specified
  - Air Force would pay for the basic CV-22 production
  - Special Operations Command would pay for special operations forces-unique CV-22 equipment
- **On April 4, 1997, the Under Secretary of Defense for Acquisition and Technology**
  - Approved low-rate initial production
  - Delegated future production decisions to Navy
- **CV-22 Block 0 Engineering and Manufacturing Development (EMD) is funded in the Navy's budget to a maximum of \$560 million (raised from \$550M)**
- **Projected cost is estimated at \$657M (\$97M over the cap)**
- **Program Manager projects funding cap to be exceeded by June 2002 with no source for additional funds identified**



Panel to Review  
the V-22 Program

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## **CV-22 BLOCK 0 DEVELOPMENT FUNDING Possible Conclusions**

- a. The funding cap restricts accomplishment of minimal essential requirements for Initial Operational Capability**
- b. If cap is removed; funding responsibility must be identified**
- c. Because the aircraft is currently grounded, and the monthly spending rate has slowed, the program is vulnerable to funds migrating to other Service programs. If this occurs, funds may not be available to complete necessary work.**



Panel to Review  
the V-22 Program

## **CV-22 BLOCK 0 DEVELOPMENT FUNDING Possible Recommendations**

- a. Remove the CV-22 Block 0 funding cap**
- b. Fund at required levels**
- c. Retain funds in the program until the Secretary of Defense considers the Panel's specific recommendations**



Panel to Review  
the V-22 Program

## **SPARES ADEQUACY**

### **Discussion**

- **Adequate spare parts have a direct relationship on readiness**
- **The adverse impact on readiness was demonstrated during Operational Evaluation as components failed at rates higher than predicted and spares were not adequate. Additionally, the Program Office did not assume, in a timely manner, the Government's responsibility for spares to support LRIP aircraft**
- **Lack of replacement parts for frequently failed components have resulted in delivery delays to the users and/or cannibalization of other aircraft (OPEVAL and Amarillo)**
- **Over \$700 million in spares in the out-years was reduced by DoN by allowing amphibious ships to share V-22 spares (5 ships share 2 sets of spares)**
- **Navy independent cost estimate (NCCA) indicated spares underfunded by over \$600M**



Panel to Review  
the V-22 Program

## **SPARES ADEQUACY Discussion**

- **Navy routinely funds spare parts to approximately 85% of the projected requirement because**
  - **High level of unique spare parts result in excess unusable inventory**
  - **An assumed commonality between platforms**
  - **Unpredictable and changing spares demand**  
**sometimes imposed by new technology**
- **As the year progresses, and actual usage rates develop, the Navy can and does supplement programs in need**
- **Over the last five years V-22 spares were funded to 100% of the Program Office's request which was based on 100% of the Navy spares model. However, actual spares requirements are higher than predicted.**



Panel to Review  
the V-22 Program

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## **SPARES ADEQUACY**

### **Possible Conclusions**

- **Production line experience and fleet data indicate that planned spare parts availability has been inadequate to sustain fleet operations**



Panel to Review  
the V-22 Program

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## **SPARES ADEQUACY**

### **Possible Recommendations**

- a. Provide for spare parts levels based on an analysis of experience to date**
- b. Fund additional engineering change proposals (ECPs) to improve reliability and reduce spare parts requirements**



Panel to Review  
the V-22 Program

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## **V-22 AIRCRAFT MODIFICATIONS Discussion**

- **Modifications are required to correct deficiencies in the existing design**
- **Navy funding for V-22 modifications was inadequate**
  - **Navy typically allows approximately 2% for engineering changes at mature production**
  - **V-22 funds to date significantly less**
- **Retrofit (modification of fielded aircraft) requires establishment of a separate funding line (Aircraft Procurement Navy -5) and identification of funds**
- **CV-22 needs to be budgeted for retrofit**



Panel to Review  
the V-22 Program

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## **V-22 AIRCRAFT Modifications Possible Conclusions**

- a. It is important that ECPs be incorporated into the production line as soon as possible**
- b. Field retrofits must be funded**
- c. Current resource (funding and personnel) realities limit the number of ECPs and retrofits that can be executed in a given fiscal year**



Panel to Review  
the V-22 Program

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## **V-22 AIRCRAFT Modifications Possible Recommendations**

- a. Maintain Low-Rate Initial Production until both the aircraft design and manufacturing processes stabilize**
- b. Increase the ECP resources at a higher level from Program savings resulting from reduced production**
- c. Establish an Aircraft Procurement Navy-5 funding line and fund retrofit of fielded aircraft**



Panel to Review  
the V-22 Program

## **Analyses of Alternatives Discussion**

- **The Marine Corps' CH-46E and CH-53D**
  - **40 year-old technology**
  - **Technical obsolescence**
  - **Degraded performance, reliability, availability, and maintainability**
  - **Out of production**
- **U.S. Special Operations Command (SOCOM) MH-53J/M Pave Low**
  - **30 year-old technology**
  - **Limited self-deployment capability**
  - **Inadequate combat radius and speed to execute missions**
  - **Inadequate growth potential to address future threats**
  - **Out of production**



Panel to Review  
the V-22 Program

## **Analyses of Alternatives Discussion**

- **Studies over the last 20 years**
  - **V-22's speed, range, payload and increased survivability provide greater operational effectiveness**
    - **Distinct advantage over helicopters in long-range, time-sensitive missions**
    - **Speed and range contribute to survivability and reduce attrition**
  - **V-22 is more effective and productive than all alternatives, but more costly than most helicopter alternatives**
- **Panel did not review Special Access Programs nor Defense Advanced Research Projects Agency (DARPA) studies**
- **Current Effort: Ongoing PA&E assessment with updated:**
  - **Costs**
  - **Demonstrated performance**
  - **Other alternatives**
  - **Results due in late April**



Panel to Review  
the V-22 Program

## Analyses of Alternatives Discussion

- **For Marine Corps**
  - **Current assets aging and replacement aircraft not in production**
  - **All alternatives (MV-22 and helicopters) improve operational capability over existing fleet**
  - **Current Primary Aircraft Assigned (PAA) undersupported**
  
- **For SOCOM**
  - **Current assets aging and replacement aircraft not in production**
  - **CV-22 is the only alternative that meets long-range infil/exfil requirement within one period of darkness**
    - **Outgrowth of Iranian hostage rescue attempt**
  - **CV-22 requires less sustainment infrastructure and strategic airlift**
  - **SOCOM has already reduced force structure (e.g. tankers) in anticipation of receiving the CV-22**



Panel to Review  
the V-22 Program

## **ALTERNATIVES TO V-22**

### **Possible Conclusions**

- a. There are a number of current aircraft that could carry out lesser missions or execute the V-22's end-mission with reduced probability of success.**
- b. If operational need is legitimate, the V-22 program will have to be restructured to address deficiencies**
- c. For the Marine Corps and SOCOM; the combination of speed, range, payload, survival, and self-deployment offer the warfighter the greatest possibility of success while minimizing casualties**
- d. The sensitivity of the SOCOM mission is sufficiently great to place a high premium on first-time success**
- e. Initiating an all-new development tends to exchange known challenges for unknown challenges--and there is no reason to believe it would cost less nor provide significantly greater capability than the V-22 (while necessitating extending the life of current inventory)**



Panel to Review  
the V-22 Program

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## V-22 Program

# Summary



Panel to Review  
the V-22 Program

## Possible Summary Conclusions

- **Flight Safety**
  - There is no inherent safety flaw in the V-22 design concept
  - Flight Crew training is adequate, but needs continuous attention
  - System reliability is adequate, major issues remain with the hydraulics system
  - The quality program is adequate, although some issues remain
- **Combat Effectiveness**
  - The V-22 demonstrated the performance to accomplish the mission
  - The V-22 is maintainable, but major issues remain
  - The maintenance training is adequate
  - The reliability and availability are inadequate, improvement plan appears satisfactory
- **Programmatics**
  - The V-22 shows many of the signs of an under funded program
  - If the requirement is valid, the V-22 appears to be the best alternative

*Should the DOD proceed with the V-22 program?*



Panel to Review  
the V-22 Program

## Possible Summary Recommendations The Way Forward

- a. Proceed with restructured program: use phased approach to return to flight and tactical introduction. Specific recommendations cover:**
- **Minimum sustainable production rate in the near-term**
  - **Adequate and stable funding**
  - **Requirements validation**
  - **Safety (hardware, software, operations)**
  - **Reliability and maintainability**
  - **Quality**
  - **Training**
  - **Tech publications**
  - **Communications across program (operators, contractors, engineers, etc)**